Survey of Northern Abalone, *Haliotis kamtschatkana*, Populations at Malcolm Island and Cormorant Island, British Columbia, October 1999 [Revised]

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SURVEY OF NORTHERN ABALONE, *Haliotis kamtschatkana*, POPULATIONS AT MALCOLM ISLAND AND CORMORANT ISLAND, BRITISH COLUMBIA, OCTOBER 1999 [REVISED]

by

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ABSTRACT

Lucas, B.G., D. Brouwer, and A. Campbell. 2002. Survey of northern abalone, *Haliotis kamtschatkana*, populations at Malcolm Island and Cormorant Island, British Columbia, October 1999. [Revised] Can. Manuscr. Rep. Fish. Aquat. Sci. 2620: 11 p.

A population census was conducted to provide an estimate of population numbers of mature emergent abalone in areas near Malcolm Island, British Columbia during October 5 – 7, 1999. The abalone encountered in these surveys were generally large and most were dispersed, even though the habitat was extensive and appeared ideal for abalone. The estimated mean density for abalone of all sizes was 0.05/m^2 at Cormorant Island, 0.04/m^2 at Bere Bay, and 0.03/m^2 at Trinity Bay. The estimated mean total population number (and 90% confidence interval) for all sizes at Cormorant Island was 3614 (952 – 6276), at Bere Bay was 5081 (673 – 9490), and at Trinity Bay was 4038 (2016 – 6059) emergent abalone. The mean total population number (and 90% confidence interval) in the 120 – 140 mm SL size range was estimated for Cormorant Island to be 943 (231 – 1655), for Bere Bay to be 4033 (134 – 7932), and for Trinity Bay to be 2550 (1692 – 3408) emergent abalone. The low densities indicate that the removal of any abalone from these areas must be considered with caution.

RÉSUMÉ

Lucas, B.G., D. Brouwer, and A. Campbell. 2002. Survey of northern abalone, *Haliotis kamtschatkana*, populations at Malcolm Island and Cormorant Island, British Columbia, October 1999. [Revised] Can. Manuscr. Rep. Fish. Aquat. Sci. 2620: 11 p.

Nous avons effectué un dénombrement de la population pour estimer les effectifs d'ormeaux matures exondés dans les régions proches de l'île Malcolm (Colombie-Britannique), du 5 au 7 octobre 1999. Les ormeaux observés pendant les relevés étaient généralement de grande taille, et la plupart étaient dispersés, même si l'habitat favorable abondait et semblait idéal pour l'espèce. La densité moyenne estimée des ormeaux de toutes tailles était de 0,05/m^2 à l'île Cormorant, 0,04/m^2 dans la baie Bere, et 0,03/m^2 dans la baie Trinity. L'effectif moyen estimé de la population totale (intervalle de confiance de 90 %) pour toutes les tailles était de 3614 (952 – 6276) à l'île Cormorant, de 5081 (673 – 9490) dans la baie Bere et de 4038 (2016 – 6059) dans la baie Trinity pour les ormeaux exondés. L'effectif moyen estimé de la population totale (intervalle de confiance de 90 %) dans la catégorie de taille de 120 – 140 mm LS était de 943 (231 – 1655) à l'île Cormorant, de 4033 (134 – 7932) dans la baie Bere et de 2550 (1692 – 3408) dans la baie Trinity pour les ormeaux exondés. Étant donné les très faibles densités observées, tout prélèvement d'ormeaux dans ces régions doit être envisagé avec prudence.

INTRODUCTION

Northern abalone, *Haliotis kamtschatkana*, populations have declined in British Columbia (B.C.), despite complete closure of the fishery since 1990 for conservation purposes. Post-harvest surveys indicated that abalone densities were still well below levels recommended to ensure sustainable populations (Breen 1986, Campbell et al. 1998). The future of *H. kamtschatkana* was sufficiently uncertain that in April 1999 this species was declared "Threatened" by COSEWIC (Committee on the Status of Endangered Wildlife in Canada).

Fisheries and Oceans Canada (DFO), in cooperation with coastal communities and other interested stakeholders, has begun an initiative to rehabilitate abalone stocks in B.C. Collection of broodstock will be required to implement the first step in this program, which is to develop aquaculture technology for this species.

To estimate abalone stocks in areas of interest, an independent assessment using conventional survey methodology was required. Only emergent abalone were surveyed to provide a minimum estimate of mature adult population numbers; cryptic abalone were not surveyed in this census.

The objectives of this study were to determine densities, size frequencies, and population numbers of mature emergent northern abalone using standard survey methods.

MATERIALS AND METHODS

FIELD METHODS

This survey was conducted October 5 – 7, 1999, at Cormorant Island, Malcolm Island, and the Holford Islets, B.C. (Figure 1). On Cormorant Island, the Yellow Bluff area was surveyed. On Malcolm Island, two areas on the north side of the island were surveyed, Bere Bay and Trinity Bay. Reconnaissance dives were conducted at Donegal Head on Malcolm Island, and at Holford Islets. Survey areas were selected, in consultation with Kwakuitl Territorial Fisheries Commission (KTFC) and Malcolm Island Shellfish Co-operative (MISC) representatives, to include areas where abalone were most abundant. The transect survey method (Cripps and Campbell 1998) was used for this study. Within each area, transects were located approximately 75 m apart at Cormorant Island and approximately 100 m apart at Malcolm Island. The primary sampling unit was a "transect", made up of a cluster or variable number of secondary units, or quadrats. Each transect was 1 meter wide and variable in length, depending on the slope of the substrate. Because the slope of the substrate was negligible, the potential length of transects in the depth range where abalone might be found was extremely long. Therefore, transects began at the outer edge of the kelp zone and extended towards and perpendicular to the shore, along a compass bearing, until eelgrass beds or extensive sand signified the end of habitat suitable for abalone. Transects were surveyed from the deepest end of the transect to the shallow end. The secondary sampling unit consisted of a 1 m x 1 m square quadrat that was placed along the transect, 1 m away, to avoid sampling areas disturbed by the

lead line placement. Divers flipped the quadrat parallel to the transect line, from deep to shallow, and the number of "emergent" or "exposed" (visible on rocks) abalone, shell length (SL in mm) of each abalone, depth, substrate type, slope, and algal cover was recorded. Algal cover, sea urchins or starfish that might have impeded detection of abalone were removed from the quadrat to ensure all emergent abalone were detected. Boulders were not moved to examine for cryptic abalone, since the majority of mature abalone (i.e., $\geq$ 70 mm SL) are exposed (Campbell 1996). On Cormorant Island, every quadrat was sampled completely (i.e., abalone, substrate and algae) in a total of seven transects. Because of the extensive length of the transects on Malcolm Island, not every quadrat along the eight transects in Bere Bay was sampled completely. On five transects, every quadrat was sampled for abalone (i.e., number, SL, and depth of abalone), and every fifth quadrat was sampled completely. On three transects, every second quadrat was sampled completely. In Trinity Bay, all quadrats were sampled for abalone and every fifth quadrat was sampled completely. All abalone within sampled quadrats were counted and measured, but because so few abalone were encountered within quadrats, nearby abalone outside quadrats were also noted and measured. Only those abalone within the quadrats were included in density calculations and size frequency analyses.

ANALYTICAL METHODS

All gauge depths were converted to depth (m) at chart datum. The survey results were analyzed according to Fisheries and Oceans Canada methodology (Campbell et al. 1999). To determine the size frequency distribution for an area, the number of abalone in each 10 mm SL size class was divided by the total number of abalone in each area.

The estimated mean density, $\bar{d}$ (number/m^2), of abalone was calculated as:

$$\bar{d} = \frac{\sum_t (d_t * L_t)}{\sum_t L_t} \qquad (1)$$

The standard error of the mean density, se_d, was calculated as:

$$se_d = \sqrt{1 - \frac{n}{T}} * \sqrt{\frac{\sum_t (d_t * L_t - \bar{d} * L_t)^2}{n * (n-1) * \bar{L}^2}} \qquad (2)$$

where n is the number of transects, d_t is the mean density (number/m^2) at transect t, L_t is the length of transect t (or area in square metres since each transect is one metre wide), $\bar{L} = \frac{\sum_t L_t}{n}$ is the mean transect length (or mean area in square metres), and T is the total possible number of transects that can be sampled in the surveyed area. The expression $\sqrt{1 - \frac{n}{T}}$ is approximately one,

because the sample size n is small compared to T. This method accounts for the variable length of transects and for the variable proportion of quadrats surveyed along each transect.

To estimate the mean densities for a specific size group (J), e.g., 90 – 110 mm SL, the value d_t was substituted with densities ($P_{t,J}$) in equations 1 and 2. The mean density $P_{t,J}$ of abalone of size group J in transect t was calculated as:

$$P_{t,J} = \frac{\left(N_t * \frac{\sum_{i \in J} m_{t,i}}{M_t} \right)}{S_t} \qquad (3)$$

where J is a subset (e.g., 90 – 110 mm SL) of possible i values representing a range of shell lengths (SL_i), S_t is the number of quadrats surveyed for density estimates in transect t, N_t is the number of abalone counted in transect t, $M_t = \sum_i m_{t,i}$ the total number of abalone measured for size in transect t, and $m_{t,i}$ is the number of abalone in size range J of transect t.

The approximate lower 90% confidence interval of the mean density (L90CI) was calculated as:

$$\text{L90CI} = \bar{d} - t_{\alpha/2} \cdot se_d \qquad (4)$$

where $t_{\alpha/2}$ is the critical t-distribution value at degrees of freedom of n-1.

The total number of abalone (X) in each abalone bed area was calculated as:

$$X = \bar{d} \cdot A \qquad \text{or} \qquad X = \text{L90CI} \cdot A \qquad (5)$$

where L90CI is the lower 90% confidence interval of the mean density for all sizes or for a particular size group of abalone, and A is the estimated area (m^2) of the surveyed location. The area of the location surveyed was calculated as the product of the mean transect length (since transects generally covered the breadth of suitable abalone habitat) and the length of the location as measured by the distance the between the two furthest shoreline points used when generating random transects.

RESULTS

All areas surveyed near Malcolm Island had a moderate exposure to wind and storms. The substrates were scattered boulders covered with encrusting corraline algae, along with gravel, sand, and cobble. Bere Bay and Trinity Bay were shallow with almost no slope. Cormorant Island had a moderately dense canopy of *Nereocystis luetkeana*, Trinity Bay had a moderately dense canopy of *Macrocystis integrifolia*, and Bere Bay had a mixed canopy containing both species of algae (Table 1). In some areas the canopy was extremely dense, and

there were also numerous broken kelp stems suggesting a formerly very dense canopy. Abundant *Laminaria*, *Costaria*, and *Cymathere* were the major components of the understory. Holford Islets had a thick canopy of *Nereocystis* on a narrow reef extending from the northwest shore. Donegal Head had a thin to moderate canopy of *Nereocystis*. Few red sea urchins (*Strongylocentrotus franciscanus*) or sunflower starfish (*Pycnopodia*) were sighted during the survey.

The depths surveyed ranged from -1.13 to 10.76 m from datum (Table 2). Seven transects, with a mean length of 64 m, were surveyed near Cormorant Island (Tables 2, 3). At Malcolm Island, 8 transects were surveyed in Bere Bay and 4 transects were surveyed in Trinity Bay, with mean transect lengths of 100 m and 185 m, respectively. Twenty-three abalone were found in quadrats near Cormorant Island, 25 in Bere Bay, and 19 in Trinity Bay, for a total of 67 abalone. Three transects surveyed had no abalone. The maximum density for a transect was 0.13 abalone/m^2. Exploratory jump dives at Donegal Head found no abalone, and at Holford Islets found 5 abalone.

Sizes of abalone surveyed at Cormorant Island ranged from 68 to 139 mm SL (Figure 2A). Sizes of abalone found at Malcolm Island ranged from 65 to 152 mm SL at Bere Bay and from 88 to 144 mm SL at Trinity Bay (Figure 2B, 2C). Most of the Malcolm Island abalone were > 120 mm SL. The sizes of abalone found at Holford Islets ranged from 60 to 122 mm SL. The mean size of emergent abalone was 103 mm SL at Cormorant Island, 130 mm SL at Bere Bay, and 125 mm SL at Trinity Bay.

Mean total densities of all emergent abalone from all locations were < 0.06/m^2 (Table 4). Density could not be estimated for Holford Islets, because a standard survey was not conducted. Mean population estimates range from 3614 to 5081 emergent abalone in the areas surveyed. Nearly all of the abalone found were mature (≥ 70 mm SL), with no abalone < 60 mm SL being found. Mean estimates of the number of abalone in the 90 – 110 mm SL size range were 0 to 786, and in the 120 – 140 mm SL size range were 943 to 4033 abalone.

DISCUSSION

Abalone on Cormorant Island were of various sizes, but most of the abalone in the surveyed area of the northern side of Malcolm Island were large. Abalone in the 90 – 110 mm SL size range were not abundant, therefore a larger size range (i.e., 120 – 140 mm SL) was also used for abalone population estimates. A conservative estimate of the total population numbers of emergent abalone of all sizes was provided by the lower 90% confidence interval (L90CI), which was 952 for Cormorant Island, 673 for Bere Bay, and 2016 for Trinity Bay. The L90CI for mature emergent abalone 120 – 140 mm SL abalone was highest for Trinity Bay (1692), followed by Cormorant Island (231), and then Bere Bay (134). The large uncertainty surrounding the estimated population means results, in part, from the small sample sizes. The lower confidence intervals provide more conservative estimates of population size than the mean estimates.

This survey provides no evidence of recovery of abalone populations since the province-wide closure in 1990. The abalone found in this survey were sparsely distributed, despite the excellent habitat. Anecdotal evidence suggests these areas have suffered recent declines in abalone abundance, probably due to illegal harvesting. The combination of large and disperse abalone at Bere Bay and Trinity Bay suggests that the reproductive success and recovery of abalone populations there may suffer from the Allee effect (Allee 1931). The abalone densities found during this survey are generally an order of magnitude lower that most recent surveys in B.C. (Campbell et al. 1998). Since these low densities are well below those recommended to ensure sustainable populations (Breen 1986), the removal of any abalone from these areas must be considered with caution.

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Table 1. Habitat summary for abalone transects surveyed in the Malcolm Island area, October 5 – 7, 1999. All areas surveyed had moderate exposure to storms. The most common substrates are listed (1 = first, 2 = second, 3 = third) where substrate code 1 = smooth bedrock, 2 = bedrock with crevices, 3 = boulders, 4 = cobble, 5 = gravel, 6 = pea gravel, 7 = sand, 8 = shell, and 9 = mud. The average slope of the transect is estimated in degrees from horizontal. The algae present are listed by height strata (canopy = tall shading surface reaching, understory = 30 cm – 2 m, turf = 5 cm – 30 cm and bottom cover = < 5 cm) for the most common species (Sp 1) and second most common species (Sp 2) with the estimated percentage of cover (%) for each. AC = articulated coralline, AG = *Agarum*, AL = *Alaria*, B = unknown brown, CO = *Costaria*, CY = *Cymathere*, EN = encrusting corraline, LA = *Laminaria*, MA = *Macrocystis*, NT = *Nereocystis*, UL = *Ulva*, and ZO = *Zostera*.

						Algae													
		Substrate			Slope	Canopy				Understory				Turf				Bottom Cover	
Transect	Date	1	2	3	degrees	Sp 1	%	Sp 2	%	Sp 1	%	Sp 2	%	Sp	%	Sp 2	%	Sp 1	%
Cormorant Island																			
CI-1	Oct 5	3	7	4	10	NT	80			LA	50	CO	50	UL	5			EN	70
CI-2	Oct 5	3	4		2	NT	25			LA	50	CO	50						
CI-3	Oct 5	7	3	5	2	NT	10			LA	50	CO	50						
CI-4	Oct 5	3	7	5	10	NT	80			LA	75	CO	50	UL	2			EN	80
CI-5	Oct 5	3	5		5	NT	15			LA	70	AG	30	AC	10				
CI-6	Oct 5	5	3		5	NT	55			AG	80	LA	10						
CI-7	Oct 5	3	7	5	5	NT	10			LA	10			UL	80			EN	75
Malcolm Island, Bere Bay																			
BB-1	Oct 6	3	4	5	2	MA	50			CY	60	LA	30						
BB-2	Oct 6	3	5	7	1	NT	20	MA	30	LA	50	CO	50						
BB-3	Oct 6	3	4		2	MA	30			LA	80	CY	20						
BB-4	Oct 6	3	4	5	2	MA	40			LA	80	AL	20	AC	10			EN	90
BB-5	Oct 6	3	5	7	1	NT	30	MA	30	LA	50	CO	50	AC	10	ZO	5	EN	80
BB-6	Oct 6	3	4	7	2	MA	40			LA	30	CO	20	B	60			EN	60
BB-7	Oct 6	3	5	5	1	NT	30	MA	30	LA	50	CO	50					AC	10
BB-8	Oct 6	3	4	5	2	MA	40	NT	20	CY	50	AL	30						
Malcolm Island, Trinity Bay																			
TB-1	Oct 7	3	5	7	1	MA	70			LA	30	CO	10	AC	50	B	2	EN	80
TB-2	Oct 7	3	5	7	0	MA	10	NT	10	LA	60	CO	10						
TB-3	Oct 7	3	5	7	1	MA	60			LA	60								
TB-4	Oct 7	3	5	7	1	MA	60			LA	60								

Table 2. Dive summary for abalone transects surveyed in the Malcolm Island area, October 5 – 7, 1999.

		Time		Bottom	Depth (m)		Number of	Total #	Density
Transect	Date	Start	Finish	Time	Min	Max	Quadrats	of Abalone	(#/m^2)
Cormorant Island									
CI-1	Oct 5	10:36	11:04	0:28	2.04	8.26	41	4	0.10
CI-2	Oct 5	10:25	10:58	0:33	0.82	7.41	41	5	0.12
CI-3	Oct 5	11:17	12:15	0:58	-0.15	7.80	78	1	0.01
CI-4	Oct 5	11:19	12:15	0:56	1.71	5.94	46	5	0.11
CI-5	Oct 5	14:05	14:45	0:40	-0.76	10.76	92	0	0.00
CI-6	Oct 5	15:09	15:50	0:41	3.11	10.49	60	6	0.10
CI-7	Oct 5	16:00	16:40	0:40	0.67	8.11	87	2	0.02
Malcolm Island, Bere Bay									
BB-1	Oct 6	10:34	10:53	0:19	1.28	2.96	60	2	0.03
BB-2	Oct 6	10:45	11:37	0:52	-1.13	2.83	74	0	0.00
BB-3	Oct 6	11:02	11:26	0:24	0.43	3.63	55	5	0.09
BB-4	Oct 6	11:43	12:18	0:35	-0.64	1.55	140	2	0.01
BB-5	Oct 6	13:54	14:15	0:21	1.07	2.16	17	0	0.00
BB-6	Oct 6	13:56	14:16	0:20	1.31	2.80	78	1	0.01
BB-7	Oct 6	14:35	15:30	0:55	0.06	2.35	71	9	0.13
BB-8	Oct 6	14:29	15:17	0:48	1.22	3.05	145	6	0.04
Malcolm Island, Trinity Bay									
TB-1	Oct 7	10:44	11:56	1:12	0.37	3.11	250	9	0.04
TB-2	Oct 7	11:10	12:25	1:15	1.77	3.44	230	6	0.03
TB-3	Oct 7	13:09	13:36	0:27	-0.79	3.41	130	3	0.02
TB-4	Oct 7	14:09	14:33	0:24	1.77	3.99	130	1	0.01

Table 3. Summary statistics and area surveyed for transect survey of emergent abalone from the Malcolm Island area, October 5 – 7, 1999. Values in brackets are standard errors.

Details per transect	Cormorant Island	Bere Bay	Trinity Bay
Dates	Oct 5	Oct 6	Oct 7
Number of transects	7	8	4
Mean transect length (m)	63.57 (24.03)	99.88 (35.31)	185.00 (92.50)
Mean depth (m)	5.01 (0.13)	1.49 (0.04)	2.19 (0.04)
Mean number of quadrats	63.57 (24.03)	80.00 (28.28)	185.00 (92.50)
Mean minutes	34.25 (12.95)	42.29 (14.95)	49.50 (24.80)
Mean minutes/quadrat	0.54 (0.12)	0.82 (0.13)	0.25 (0.03)
Shoreline surveyed (m)	1100	1200	850
Area surveyed (m^2)	69927	119856	157250

Table 4. Population estimates of emergent abalone from the Malcolm Island area, October 5 – 7, 1999. Values in brackets are 90% confidence intervals, # = number.

Details per location	Cormorant Island	Bere Bay	Trinity Bay
Mean density all sizes (#/m^2)	0.05 (0.01-0.09)	0.04 (0.01-0.08)	0.03 (0.01-0.04)
Mean density 90-110 mm SL (#/m^2)	0.01 (0.00-0.02)	0	0.00 (0.00-0.01)
Mean density 120-140 mm SL (#/m^2)	0.01 (0.00-0.02)	0.03 (0.00-0.07)	0.02 (0.01-0.02)
Total population all sizes	3614 (952-6276)	5081 (673-9490)	4038 (2016-6059)
Population 90-110 mm SL	786 (-103-1674)	0	425 (19-831)
Population 120-140 mm SL	943 (231-1655)	4033 (134-7932)	2550 (1692-3408)

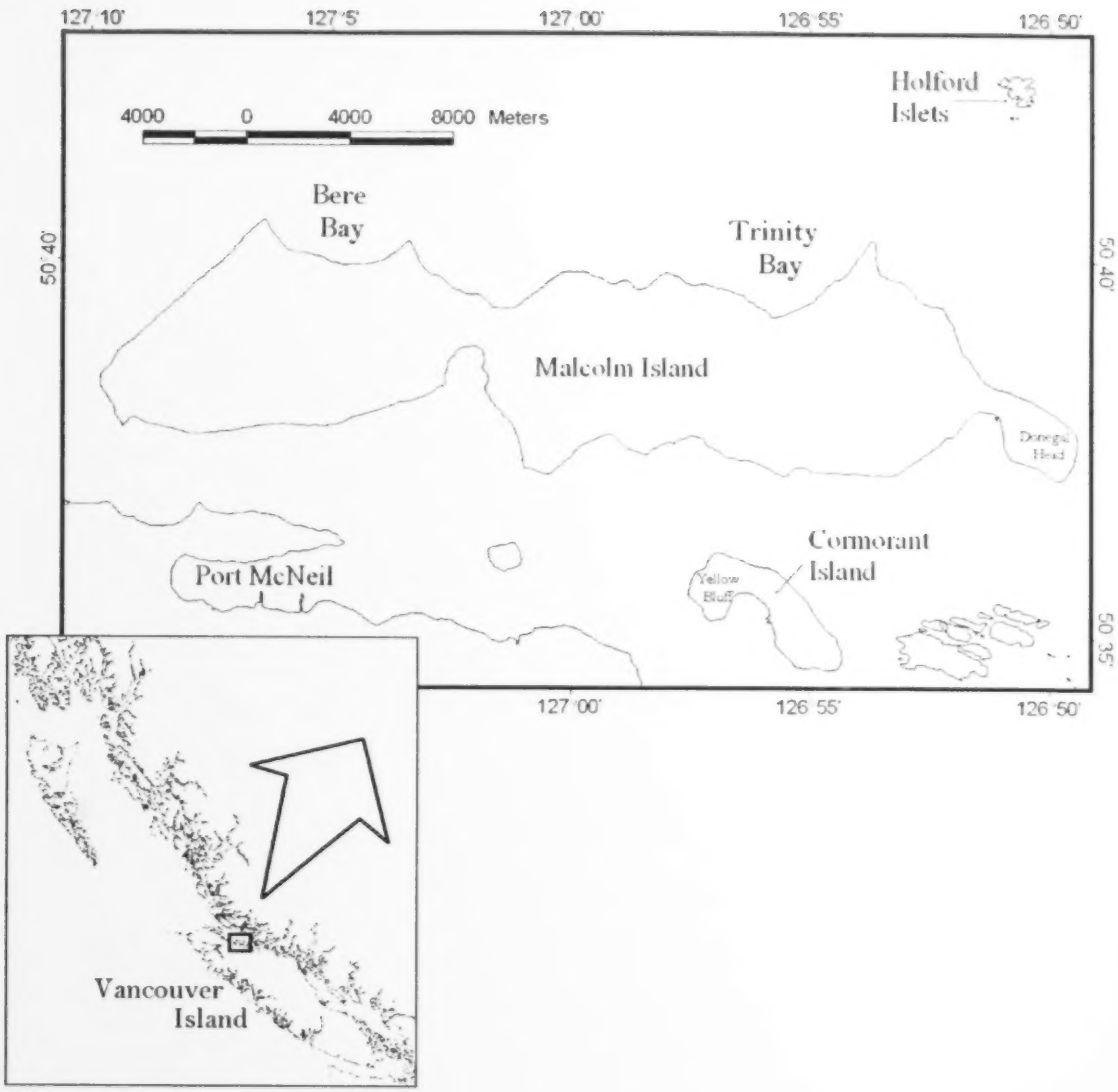

Figure 1. Abalone were surveyed on Cormorant Island, Malcolm Island, and the Holford Islets, October 5 – 7, 1999. The inset of British Columbia shows the area of Vancouver Island detailed on the map.

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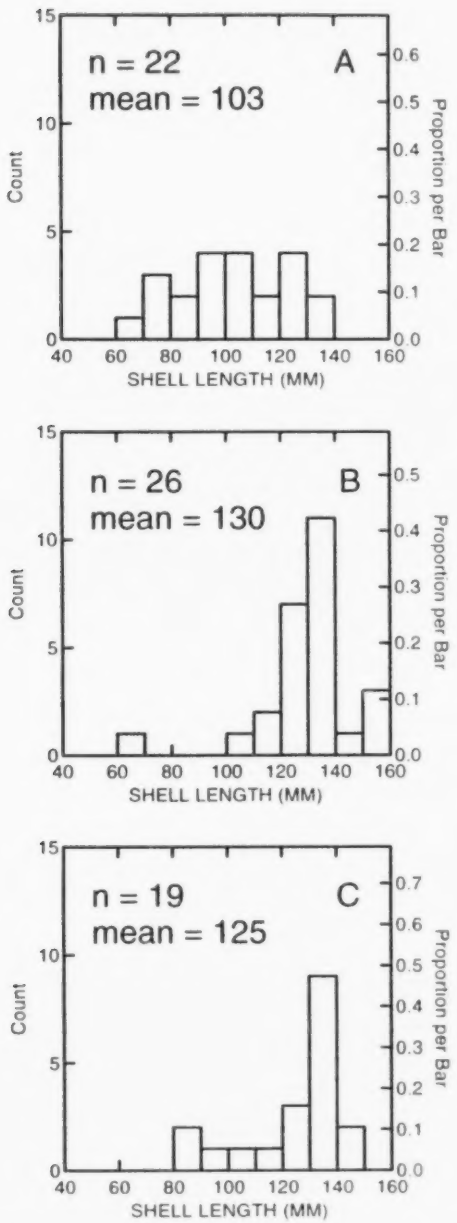

Figure 2. Size frequencies of emergent abalone found in quadrats during dive surveys in the Malcolm Island area, October 5 – 7, 1999. Locations were (A) Cormorant Island, (B) Bere Bay, Malcolm Island, and (C) Trinity Bay, Malcolm Island. Number of abalone (N) and mean shell length in mm are shown.